

# Unleashing GREEN

## Chemistry and Engineering in Service of a Sustainable Future

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## EXECUTIVE SUMMARY

From schools and universities to the private sector to government, consumers, policymakers, advocates, students and educators are each advancing the cause of sustainability. Efforts to promote more ecologically-oriented design, clean technology, clean energy, green jobs, eco-innovation, lifecycle thinking and related concepts might have different focal points, but they have in common the goal of creating a society grounded in the three pillars of sustainability: environment, economy and social equity. If we look to the heart of our industrial order and understand how materials and products are created, transformed and disposed of, we find that green chemistry is an essential piece to creating a sustainable society.

Green chemistry is the science of creating components and processes that are sustainable from the very beginning of the lifespan of a product. By designing and creating better building blocks at the design stage, products and technologies can have vast benefits, including reduced pollution and other hazards to health and the environment, increased efficiency, and enhanced performance.

This report seeks to bring together and highlight leaders in Region 2 in green chemistry and related fields. Region 2 has a strong track record of effective pollution prevention programs, innovative industry, and successful educational institutions and sustainability initiatives. Using these existing frameworks, a variety of possible pathways offer insight and promise for integrating green chemistry into the broader economy. Building awareness, increasing knowledge and developing skills will create healthier individuals, schools, workplaces and communities that can help build a sustainable society.

## PREFACE

This report is designed to complement and build on the EPA workshop *Unleashing Green Chemistry and Engineering in Service of a Sustainable Future*, which was held on September 23, 2011 in New York City. Beyond Benign, as a subcontractor to BLH Technologies, Inc., under EPA contract No. EP-C-08-032, produced this report at the request of EPA Region 2, with the purpose of:

- Providing a general introduction to green chemistry and engineering, including more specific informational resources;
- Describing the potential benefits of green chemistry; and
- Identifying example activities and capabilities that illustrate current implementation of green chemistry and engineering in Region 2.

This report is being presented to EPA Region 2 and is not a statement of policy by EPA or any of its regional offices. However, it does suggest different ways in which stakeholders in Region 2 can come together to support the application of the principles of green chemistry and engineering in the development of the regional economy and educational system. The report suggests possible pathways that can provide EPA Region 2 and other regional offices an opportunity to consider how they may advance green chemistry and engineering in their own situations.

Due to limits in time and funding, this report only concentrates on work on green chemistry and green engineering being done in New Jersey and New York, although Region 2 also comprises Puerto Rico and the U.S. Virgin Islands.

## INTRODUCTION

The question of sustainability—how to meet “the needs of the present without compromising the ability of future generations to meet their own needs,” as the landmark 1987 Brundtland Report phrased it—is arguably the greatest challenge our society faces today.<sup>1</sup> How can we live well within the means of nature? Answering this question means shifting and transforming our attitudes toward nature not only on *where* we live, but also on creating a model for *how* to live. Nature provides us with a set of laws that can be usefully applied in developing technologies that minimize pollution and waste, conserve resources, and improve health and well-being.<sup>2</sup> In order to realize this ideal, our society must concentrate on not only creating products that better embody natural processes, but also on creating production chains that do the same, from concept to manufacturing to disposal. This task is neither simple nor easy and will require the combined efforts of the business community, government officials, scientists, educators and the public. In particular, regional efforts to collaborate around this task will be essential to creating a thriving, sustainable society.

### What Is Green Chemistry?

Green chemistry is essential to sustainable development because of the inherent focus on *how* we make things and *what* products we create as scientists. As a science, green chemistry has been clearly defined since the publication of the book *Green Chemistry: Theory and Practice* in 1998 by Paul Anastas and John Warner. The subject addresses the heart of the pollution problem and asks molecular designers to consider creating materials and products that are sustainable from the very beginning (i.e., at the design stage). Through this approach, we can ensure that the building blocks that make up our economy are truly sustainable. If these building blocks are sustainable, then the end product will be much more likely to be sustainable as well.

Anastas and Warner’s book includes the “12 Principles of Green Chemistry,”<sup>3</sup> which are guidelines for practicing chemists to use when designing new products and processes, and which embody green chemistry as a whole:

1. **Prevention.** It is better to prevent waste than to treat or clean up waste after it is formed.
2. **Atom Economy.** Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

“...We can begin to divine a canon of nature’s laws, strategies, and principles...”

- Nature runs on sunlight.
- Nature uses only the energy it needs.
- Nature fits form to function.
- Nature recycles everything.
- Nature rewards cooperation.
- Nature banks on diversity.
- Nature demands local expertise.
- Nature curbs excesses from within.
- Nature taps the power of limits.”

—Janine Benyus in  
*Biomimicry: Innovation  
Inspired by Nature*, 1997

3. **Less Hazardous Chemical Synthesis.** Whenever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. **Designing Safer Chemicals.** Chemical products should be designed to preserve efficacy of the function while reducing toxicity.
5. **Safer Solvents and Auxiliaries.** The use of auxiliary substances (e.g., solvents, separation agents) should be made unnecessary whenever possible and, when used, innocuous.
6. **Design for Energy Efficiency.** Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.
7. **Use of Renewable Feedstocks.** A raw material or feedstock should be renewable rather than depleting whenever technically and economically practical.
8. **Reduce Derivatives.** Unnecessary derivatization (e.g., blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible.
9. **Catalysis.** Catalytic reagents, as selective as possible, are superior to stoichiometric reagents.
10. **Design for Degradation.** Chemical products should be designed so that at the end of their function they do not persist in the environment and instead break down into innocuous degradation products.
11. **Real-time Analysis for Pollution Prevention.** Analytical methodologies need to be further developed to allow for real-time in-process monitoring and control prior to the formation of hazardous substances.
12. **Inherently Safer Chemistry for Accident Prevention.** Substance and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.

Additional green chemistry resources can be found in the Appendix.

## What Is Green Engineering?

Green chemistry is one part of a broader push toward green engineering and the integration of sustainability principles into all aspects of the design process. While a discussion of green engineering itself is outside the scope of this report, it is worth mentioning some of the guiding principles in the field, as defined at a 2003 meeting<sup>4</sup> of more than 65 engineers and scientists in Sandestin, Florida:

1. Engineer processes and products holistically, use systems analysis, and integrate environmental impact assessment tools.

2. Conserve and improve natural ecosystems while protecting human health and well-being.
3. Use lifecycle thinking in all engineering activities.
4. Ensure that all material and energy inputs and outputs are as inherently safe and benign as possible.
5. Minimize depletion of natural resources.
6. Strive to prevent waste.
7. Develop and apply engineering solutions, while being cognizant of local geography, aspirations and cultures.
8. Create engineering solutions beyond current or dominant technologies; improve, innovate, and invent (technologies) to achieve sustainability.
9. Actively engage communities and stakeholders in the development of engineering solutions.

Engineering as a field utilizes a holistic systems approach to problem solving. The tools and techniques such as lifecycle analysis are complementary for designing sustainable products and processes. Green chemistry and engineering are allied and integral for a sustainable future. For more information, please refer to the Appendix.

## **The Benefits of Green Chemistry and Green Engineering**

Green chemistry and green engineering offer many benefits to scientists, educators, businesses, policymakers, and the public. For scientists, it provides a platform for not only avoiding or eliminating hazards and waste, but also for creating new, innovative, and efficient methodologies. For educators, it can be a tool for inspiring students to pursue scientific careers, providing context to a subject that is often abstract. For businesses, it can help realize cost savings through reduced waste disposal costs and reduced worker liability costs, while offering competitive advantage in existing markets, offering a greater value added to customers, and over all higher innovation potential that leads to the creation of new markets. For policymakers, it is projected to advance opportunities for environmental outcomes that go beyond what is now possible with existing regulatory policies and reduce social conflict around the trade-off between the environment and economic growth. And for the public, it means a cleaner, safer environment, as well as greater economic opportunities.

## **VISION OF GREEN CHEMISTRY INTEGRATION IN EPA REGION 2: WHAT DOES THE FUTURE LOOK LIKE?**

Cities, states and regions that take advantage of the opportunities that green chemistry presents can reap many benefits, including broadly shared prosperity and sustained economic growth. This, however, depends on such factors as whether local natural and capital resources are well managed; whether the local educational system can produce the human capital needed to fill jobs

in green chemistry; and whether public policy supports industrial innovation in green chemistry and sustainable technologies. These factors all require collaboration from many parties and strong partnerships across sectors of society. The *Unleashing Green Chemistry and Engineering in Service of a Sustainable Future* workshop held on September 23, 2011 in New York City, attended by 200 people, demonstrated the breadth and level of interest for green chemistry in EPA Region 2. A variety of stakeholders expressed interest in promoting awareness, knowledge and education of green chemistry to their various constituents. This document provides a vision of a sustainable future in EPA Region 2, which can come about through the incorporation of green chemistry principles into many organizations. Each of the following groups can play a major role in applying green chemistry throughout the region.

## **Education**

Educators convey existing knowledge and create new knowledge. Colleges and universities can prepare students entering the workforce with the skills to help solve regional and global environmental problems. Moreover, K-12 and community education serve to educate the majority of citizens on sustainability issues and how they are relevant to their daily lives. Integrating green chemistry throughout the different stages of education is essential to creating a workforce and public that is well educated in the importance and the benefits of sustainable development. Through the integration of green chemistry in educational institutions, the following benefits can be realized: healthier, safer schools; a well-informed public; higher student retention and engagement; and better preparation for the workforce.

### **Healthier, Safer Schools**

The use of green chemistry solutions can drastically reduce the number of hazardous chemicals in schools and classrooms. Often traditional chemistry lesson plans involve highly hazardous chemicals, such as heavy metals and volatile organic solvents. Adopting green chemistry in the classroom results in the complete elimination of hazardous chemicals, or use of safer chemicals, while demonstrating the same educational techniques and topics.

### **A Well-Informed Public**

Green chemistry is an opportunity to engage students, on the subject of science and sustainability, regardless of their aptitude in science. By weaving the subject throughout K-12 and college-level courses and programs, students entering the workforce in all career paths can have a greater appreciation for how chemistry plays a role in their lives and their futures. These citizens and consumers in turn will be better prepared for making decisions about product purchasing and civic responsibilities.

### **Higher Retention and Engagement**

Science subjects are often taught without context of how the concepts fit into students' daily lives or in society. Green chemistry can provide a valuable context for learning and understanding scientific subjects. With an understanding of how chemistry and related subjects

relate to our world around us, students are more engaged in learning, which leads to higher retention rates.

### **Better Preparation for the Workforce**

Academic institutions are responsible for preparing students to enter the professional workforce with the appropriate skills to work in a professional capacity. Incorporating green chemistry principles into the core required courses of chemists graduating with undergraduate or graduate degrees provides a set of tools for better designing molecules, products and processes. Green chemistry is by nature practical and applied chemistry, and therefore can provide an innovative platform for students entering the scientific workforce.

All academic institutions, including community colleges, four-year colleges, graduate institutions and teaching colleges, have a role to play in preparing a workforce with green chemistry skills. Community colleges serve to prepare a technician level workforce, which is essential for businesses to reside within a region, while pre-service teacher training programs are a critical piece to introducing future teachers at the K-12 level to basic green chemistry principles.

## **Industry**

Industries that have adopted green chemistry practices have realized numerous benefits, including competitive advantage, product and process innovation, cost savings, safer workplaces and safer communities.

### **Competitive Advantage**

Adopting green chemistry practices at the design stage of a product lifecycle offers a competitive advantage by providing industry with quicker time-to-market for their products. By designing products and processes that avoid the use of regulated and/or hazardous chemicals, time and resources can be saved in the product development process.

### **Innovation**

Green chemistry is a mechanism for innovation in industry because it incorporates new technologies and mechanisms that use systematic approaches to solving problems and creating products. There are increased opportunities for the creation of new markets and revenues through innovation. Through green chemistry, industry can be innovative within their industrial sector using safer, less hazardous materials and chemicals.

### **Cost Savings**

Green chemistry in practice leads to economic benefits due to reduction in the cost of waste management, reduced energy use, increased efficiency of materials usage, reduction in environmental and product liabilities, increased worker safety, and reduction in industrial accidents.

## **Safer Workplaces and Safer Communities**

By its very nature, green chemistry promotes the use of less hazardous chemicals in the research, development and manufacturing of industrial products and materials. Therefore, its adoption can reduce workers' exposure to threats to health and safety, as well as the surrounding community's exposure to threats from explosions and releases of hazardous materials. Businesses that have embraced the triple bottom line (people, profit and planet) are achieving success in the board room, on the stock market, and in the eyes of their community and consumers.

## **Government**

Governmental organizations and their policymakers have mechanisms in place that are fostering green chemistry research and education. At the local, state and federal levels these programs can play a key role in prioritizing and promoting green chemistry and sustainable technologies.

## **Beyond Regulations**

Government grant-making organizations can make green chemistry a priority within their region by creating or redirecting funding to support best management practices, case studies by leading organizations, as well as new, innovative research on green chemistry and sustainable technologies.

## **Stimulate the Economy**

Consistent with state-level economic development strategies, tax incentives can promote the growth of green chemistry technologies in industry. Additionally, innovation as a result of green chemistry practices can create opportunities for new markets and new revenue sources.

## **Safer Communities**

Addressing environmental health issues from a proactive and preventative approach rather than the traditional remedial approach after the fact will create products and process that are contributing in a positive way to the overall health of individuals and communities.

## **Consumer Demand**

By partnering with consumer advocacy groups, public health advocates, and environmental justice advocates, government can engage in public and consumer education on topics related to sustainability and public health. Effective partnership between government, NGOs and community-oriented organizations can form a strong base for advocacy of green chemistry technologies in order to effectively support green chemistry throughout society.

## **ROLE MODELS IN REGION 2: WHERE IS GREEN CHEMISTRY TAKING OFF AND WHO IS DOING IT?**

Creating a sustainable future in Region 2 will require creativity, innovation and collaboration. Already there are leaders within industry, state government and education who are applying green chemistry practices. Their efforts serve as models from which other stakeholder groups might draw inspiration for their own work. The following list is only a sample of the work being

done throughout Region 2. This next section helps to lay the ground work for the suggested pathways of moving green chemistry forward within the region.

## Industry

At the *Unleashing Green Chemistry* workshop, David Levine, Executive Director of the American Sustainable Business Council, highlighted the growing number of businesses adopting a triple bottom line (people, profit and planet). Sustainability is now the driver of innovation, as the *Harvard Business Review* noted in 2009,<sup>5</sup> while investments in sustainable business have risen to \$2 trillion. This figure is expected to grow to \$10 trillion by 2020.<sup>6</sup>

Sustainability concepts, practices and technologies are clearly on the rise throughout many industry sectors. In Region 2, companies are employing green chemistry and green engineering principles on a regular basis toward the design and redesign of their products and processes. Two examples demonstrating these shifts in research and decision making within Region 2 companies are presented below.

### Construction Specialties

Headquartered in Lebanon, New Jersey, Construction Specialties (CS) is a privately owned U.S. company that develops and manufactures architectural building products for non-residential construction. CS has re-engineered a vinyl/acrylic wall protection material, Acrovyn®, to eliminate polyvinylchloride (PVC) from their wall coverings and door products. The new formula achieves a UL Class 1 tested and labeled fire rating with no persistent bioaccumulative toxicants (PBTs), no bisphenol A (BPA) and no halogenated fire-retardants. This re-engineering represents a shift towards greener construction and building materials in many of the CS product lines.<sup>7</sup>

### Bristol-Myers Squibb

With corporate headquarters in New York City and research sites in New York, New Jersey, and Puerto Rico, Bristol-Myers Squibb (BMS) is one of the largest pharmaceutical companies in the world. The BMS green chemistry program uses the Process Greenness Scorecard, an internal tool designed for scientists and engineers, to identify the environment, health and safety implications of new and existing products and processes. The BMS green chemistry program can help BMS “develop innovative, cost-effective medicines that extend and enhance human life” through a number of different avenues.<sup>8</sup>

## Presidential Green Chemistry Challenge Awardees

The Presidential Green Chemistry Challenge (PGCC) is a federal program established to recognize and promote innovative chemical technologies that prevent pollution and have broad applicability in industry.<sup>9</sup> The awardees are broken down into five categories (Academic, Small Business, Designing Greener Chemicals, Greener Reaction Conditions and Greener Synthetic Pathways). Over the past 16 years, 80 challenge winners have been awarded. The Challenge is sponsored by EPA’s Office of Chemical Safety and Pollution Prevention in partnership with the

American Chemical Society Green Chemistry Institute and other members of the chemical community.

Several award winners have come from EPA Region 2, including SiGNa Chemistry (2008), NovaSterilis (2007), Merck & Co, Inc. (2005 and 2006), BASF Corporation (2005), Bristol-Myers Squibb Company (2004), Engelhard Corporation (now BASF, 2004), and Dr. Richard Gross of New York Polytechnic University (2003). For more information on the PGCC award winners, refer to the websites in the Appendix. A few of these award winners and their technologies are briefly described below.

### **SiGNa Chemistry: 2008 Small Business Award**

SiGNa Chemistry, headquartered in New York City, was awarded the 2008 PGCC award for the development of safer reagents useful for numerous applications in molecular and materials synthesis.<sup>10</sup> Alkali metals, such as sodium and lithium, are powerful tools in synthetic chemistry because they are highly reactive. However, their reactivity also makes them both flammable and explosive unless they are handled very carefully. SiGNa Chemistry developed a way to stabilize these metals by encapsulating them within porous, sand-like powders, while maintaining their usefulness in synthetic reactions. The stabilized metals are thus much safer to store, transport and handle. They may also be useful for removing sulfur from fuels, producing hydrogen and remediating a variety of hazardous wastes.<sup>11</sup>

### **NovaSterilis: 2007 Small Business Award**

NovaSterilis, a privately held biotechnology company in Ithaca, New York, has successfully developed and commercialized a highly effective and environmentally benign method for sterilizing delicate biological materials for medical applications using supercritical carbon dioxide.<sup>12</sup> Sterilization is crucial for numerous biological materials, such as donor tissues where the distribution of contaminated tissues can result in serious infections and safety concerns. The company's Nova2200™ sterilizer requires neither hazardous ethylene oxide nor gamma radiation, which are typical sterilization techniques that are toxic or have safety problems. The product is highly efficient and consistently achieves rapid and total inactivation of a wide range of microbes, including bacterial endospores.<sup>13</sup>

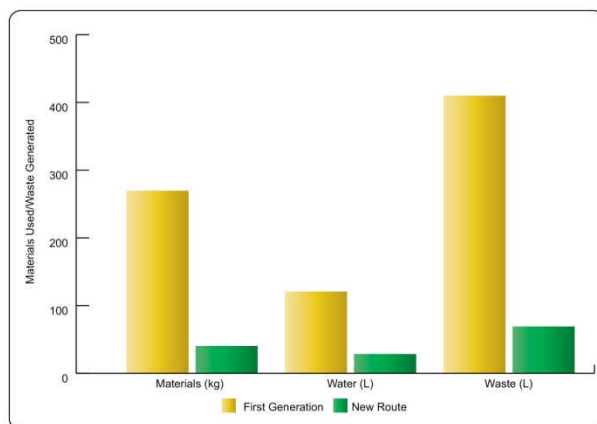
### **Merck & Co, Inc.: 2005 Synthetic Pathways Award**

Merck & Co., Inc., located in Rahway, New Jersey, was awarded a PGCC award for the redesigned, efficient synthesis of Aprepitant, the active ingredient in Enemid®, a new therapy for chemotherapy-induced emesis.<sup>14</sup> The drug is used to prevent or reduce chemotherapy-induced nausea and vomiting. In its first-generation synthesis, there were six synthetic steps, poor atom economy<sup>15</sup> and harsh reaction conditions. Typical reagents used in this synthesis were sodium cyanide, dimethyl titanocene and gaseous

"The choice to implement the new route at the outset of production has led to a drastic reduction in the cost of production of Aprepitant, demonstrating quite clearly that green chemistry solutions can be aligned with cost-effective ones."

—Merck & Co, Inc.  
Presidential Green  
Chemistry Challenge  
Award, 2005

ammonia, which are hazardous. By applying green chemistry principles to the design of Aprepitant, Merck scientists developed a synthesis that has three steps, each of which are highly atom-economical, and eliminated the use of hazardous reagents. As illustrated in Figure 1, the overall process only requires 20 percent of the raw materials necessary for the first generation synthesis, yet doubled the product yield. Switching from the old synthesis to the new one prevented the generation of 340,000 liters of waste for every 1,000 kilograms of Aprepitant produced. The e-factor<sup>16</sup>, meanwhile, was reduced from 477 to 66.<sup>17</sup>



**Figure 1. Material consumption and waste generation per kg of Aprepitant produced.<sup>18</sup>**

Additional national leaders and innovators such as NatureWorks LLC and BioAmber, Inc., shared the stage at the *Unleashing Green Chemistry* workshop by highlighting their own PGCC award-winning technologies as part of the perspectives panel. For example, BioAmber's process for producing succinic acid uses 60 percent less energy than succinic acid made from fossil fuels, offers a smaller carbon footprint, and costs 40 percent less than succinic acid made from fossil fuels.<sup>19,20</sup> NatureWorks LLC, in their synthesis of polylactic acid (PLA) polymers, eliminates organic solvents and other hazardous materials, completely recycles product and by-product streams, and efficiently uses catalysts to reduce energy consumption and improve yield.<sup>21,22</sup> For more information on these companies, please refer to their websites listed in the Appendix.

## Education

Throughout Region 2, institutions within higher education are innovating through the incorporation of green chemistry and engineering principles into their programs and research. Two leading programs and featured presenters from the *Unleashing Green Chemistry* workshop are outlined below.

### Siena College

The Siena faculty began revamping its organic chemistry curriculum shortly after attending the University of Oregon Green Chemistry training for professors in 2005. Starting with a pilot

course in spring 2006, the program has evolved to be fully integrated into all of the organic chemistry courses.

Michael O'Brien, lecturer at Siena, spoke at the *Unleashing Green Chemistry* workshop about the advantages to the Chemistry Department's shift to using a green chemistry lens for teaching and learning. Specific advantages included reduced environmental hazards, increased safety, reduced waste, increased student interest, increased student involvement and increased experimentation.

Professor O'Brien also cited some interesting challenges when applying a green chemistry lens in an organic chemistry lab setting: conditions sometimes are very specific and cannot be substituted, nor does everything "work" as expected. "But is this not exactly," said O'Brien, "where innovation happens in science when we break the mold and ask entirely different questions or receive answers that were unexpected or unintended entirely?" These challenges mean that students at Siena College are graduating better prepared as critical thinkers and scientists.

### **Rowan University**

Rowan University is a leader in Region 2 for its green engineering work. Rowan faculty and students have been leading an EPA Region 2-funded project advancing the concept of green engineering in pharmaceutical development and manufacture, an important industrial sector in Region 2, through a partnership with three major drug companies with a presence in the region: Bristol-Myers Squibb (New Brunswick, New Jersey), Novartis (East Hanover, New Jersey) and Pfizer, Inc. (New York, New York). Through this project, the Rowan team has applied the concept of lifecycle analysis to assess the environmental benefits of these pollution prevention improvements and strategies for solvent reduction and recovery operations. Rowan's unique "engineering clinic" model facilitates interventions on actual cases where Rowan faculty and student teams work with drug company scientists and engineers. According to Dr. C. Stewart Slater and Dr. Mariano J. Savelski, professors and leaders of the program at Rowan University, "the engineering clinic model is a win-win for both industry and academia. Industry gains from the exchange of new ideas and the university faculty/student team advances the knowledge base in the field. A new generation of engineers are being educated through service learning to solve problems with a green design approach."

Project outcomes from the Rowan University engineering clinics have yielded improvements in pollution prevention (P2), including waste reduction, energy savings, carbon footprint reduction and overall cost savings. One project example involves the Rowan team working with Pfizer on the redesign of the process for making Celecoxib, the active pharmaceutical ingredient in the top selling arthritis pain medicine, Celebrex®. The goal of this project was to do a design study and evaluate alternative green separation schemes for the recovery of isopropanol from waste streams in the manufacturing process of the active ingredient, which is produced in one of the major Pfizer facilities in Puerto Rico. Through innovative techniques, the Rowan team determined the

technical feasibility and estimated process P2 improvements for green design alternatives to the separation process. This project has the potential to reduce emissions generated at the plant site and throughout the solvent lifecycle.<sup>23</sup>

Rowan University and Siena College are among several institutions that have emerging green chemistry and engineering programs. These include: The City College of New York, Hartwick College, Hobart and William Smith Colleges, New York City College of Technology, Monmouth University, Pace University, Polytechnic University, Brooklyn College and SUNY Colleges at Potsdam and Oneonta. These institutions are advancing and implementing green chemistry and green engineering both internally and through collaborative programs. Pace University, for example, is set to offer a green chemistry course in fall 2012, while Brooklyn College has posted an opening for a faculty position with a focus on green chemistry.

## State Government

### NYSERDA Biomimicry Roadmap

The New York State Energy Research and Development Authority (NYSERDA) has several strategic programs promoting green chemistry or applying its principles. The agency plays a unique role as a leader in helping New York meet its goals of reducing energy consumption, promoting the use of renewable energy sources and protecting the environment.

One noteworthy effort highlighted at the *Unleashing Green Chemistry* workshop was the development of a Biomimicry Roadmap. Biomimicry (from the Greek *bios*, meaning life, and *mimesis*, meaning imitation) is a design discipline that seeks sustainable solutions by emulating nature's time-tested patterns and strategies (e.g., a solar cell inspired by a leaf). Advocates of biomimicry say that Nature, imaginative by necessity, has already solved many of the problems we are grappling with, including energy, food production, climate control, non-toxic chemistry, transportation, and packaging.<sup>24</sup> Biomimicry and green chemistry complement each other: the former draws inspiration from natural forms, functions and systems to provide inspiration and ideas for addressing sustainability challenges; while the latter provides the tools and techniques for creating the building blocks of the solutions.<sup>25</sup>

Biomimicry offers a paradigm shift in energy efficient design, the potential for which NYSERDA can harness to develop innovations that could be critical for the long-term energy performance of the State.<sup>26</sup> NYSERDA has collaborated with stakeholders from science, industry, government and advocacy to create the Biomimicry Roadmap for developing biomimicry strategies across multiple sectors. Within the Roadmap is an explicit call for encouraging skill building in green chemistry and systems-level engineering.<sup>27</sup> To read more about the Biomimicry Roadmap and connect with more resources about biomimicry refer to the Appendix.

## **NYSDEC Pollution Prevention**

The ongoing success of the New York State Department of Environmental Conservation's (NYSDEC) *Pollution Prevention Practices at NYS Schools with a Focus on Green Chemistry* grant from EPA Region 2 can serve as a model worthy of evaluation by other schools in the region and country. Aida M. Potter, P.E., Chief of The Toxics Reduction & Green Chemistry Section, Division of Materials Management of NYSDEC, has undertaken the initiative of advancing green chemistry in New York State high schools. Using green chemistry encourages teachers and students to consider the lifecycle of the chemicals they work with and promotes awareness of chemical toxicology, sustainability and the impact of their actions in the chemistry lab on the environment.

NYSDEC's pilot project, currently underway, will ultimately select four high schools from several regions of the state to participate in green chemistry training and additional workshops to help transition teachers to overall safer chemical management practices in their classrooms. The program is providing training in integrated chemicals management and instruction of teachers on how to take a chemical inventory of their labs, assess the potential hazards with the chemicals identified in the inventory, and manage, clean out or dispose any of the unwanted chemicals. NYSDEC staff and Beyond Benign are responsible for the workshops and trainings.

NYSDEC staff, as part of their grant commitment, will track the reduction of chemicals of concern and the associated costs, as well as the implementation rate of teachers who have been instructed in safer alternative lab experiments and practices. Results from the pilot project will help substantiate the need for increased student engagement, safer schools, and less costly lab supplies and waste removal costs.

The NYSDEC green chemistry pilot project is a continuation of the chemical management outreach program in New York State's schools that began in 2005 with the goal of eliminating mercury in schools. Between 2005 and early 2012 that initiative has accomplished the following:

- Removal of 1,126 pounds of mercury
- Removal of 2,055 pounds of chemical waste
- Training of staff from 2,146 schools at the 11 chemical management workshops
- Representation of 51 counties at NYSDEC mercury and chemical management workshops
- Training of 57 science teachers in green chemistry
- Training of 100 school personnel at three Environmental Compliance Assistance workshops

The early success in the State of New York has been due, in part, to financial support from EPA Region 2 and other critical strategic partnerships with The New York State Education Department, New York Board of Cooperative Educational Services (BOCES) and Siena College.

Other organizations that have helped to get information out on this ongoing pilot project include: the New York Academy of Sciences, New York State United Teachers, the New Jersey Department of Environmental Protection, Rutgers Cooperative Extension, the Water Resources Program, and Clean and Healthy New York.

## **PATHWAYS OF SUCCESS: RECOMMENDATIONS FOR THE FUTURE**

Many different pathways of success can co-exist to advance green chemistry goals and the expected economic, social and environmental outcomes within Region 2. In this section, several larger recommendations are outlined, including existing resources and potential programs and partnerships.

### **Recognition Platforms/Awards**

Recognizing businesses and other organizations' accomplishments in innovation, excellence, economic development and improvements in public health through awards programs provides an opportunity for Region 2 to highlight, celebrate and encourage green chemistry and engineering efforts. Including green chemistry in existing recognition and awards frameworks, either through broadening their focus or through adding a new green chemistry and green engineering category, is another potential way to encourage and promote green chemistry and engineering efforts.

### **State-Specific and Region 2 Examples**

The following recognition and award platforms are examples of state-specific and Region 2 awards and prizes that highlight sustainability practices and are excellent opportunities to recognize achievements for green chemistry work as well.

- NYSDEC's Environmental Excellence Awards honor eligible applicants who are meeting environmental challenges by using innovative and sustainable practices or creative partnerships.<sup>28</sup>
- The New Jersey Department of Environmental Protection (NJDEP) Governor's Environmental Excellence Awards honor and recognize individuals, businesses, educators, institutions, communities, and others that have made significant contributions to environmental protection in New Jersey.<sup>29</sup>
- EPA Region 2's Environmental Quality Award (EQA) honors individuals and organizations that have contributed significantly to improving the environment. A 2012 Environmental Quality Award was given to Ecovative Design LLC (Green Island, New York) for creating a completely compostable polystyrene substitute for packing material. In addition, another 2012 EQA went to EcoLogic Solutions, Inc., for their leadership in all natural and plant-based cleaning chemicals and technologies for offices, schools, hotels and hospitals.<sup>30</sup>

- Chemagination, a contest sponsored by the American Chemical Society (ACS) and their local chapters, engages high school students in chemistry by asking them to imagine how it will affect life in the future.<sup>31</sup> Writing an article for *ChemMatters*, a magazine for high school students that focuses on the role of chemistry in everyday life, entrants are directed to look 25 years into the future and “describe a recent breakthrough or innovation in chemistry and/or its applications that has improved the quality of people’s lives today.”<sup>32</sup> This experience engages students in learning about cutting-edge technologies as the vehicle through which the best practices of chemistry will be applied and practiced from now and into the future. Participants from New Jersey’s Princeton Section of the ACS presented a poster of student work at the *Unleashing Green Chemistry* workshop. This program can be a good way of engaging regional high school students on the subject of green chemistry.
- Green Ribbon Schools, an award launched in the spring of 2012 through the U.S. Department of Education, EPA and the White House Council on Environmental Quality recognizes public and private elementary, middle and high schools that save energy, reduce costs, protect health and exemplify environmentally sustainable learning spaces and educational programs to boost academic achievement and community engagement. Various agencies and organizations from both New Jersey and New York were involved in the selection and nomination process for this award. In the first year of the award, four schools from New Jersey and three schools from New York were recognized for their outstanding commitment to sustainable learning spaces and programs.<sup>33</sup> The Green Ribbon Schools awards process and recognition should be aligned with aspirations to promote green chemistry as part of a more sustainable learning space in schools.

## Transforming Chemistry Education

A key force for a more sustainable future is an engaged citizenry literate in scientific and environmental matters. The education system continuum, from K-12 schools to vocational training to undergraduate and graduate degree programs, provides several pathways for career and civic-minded development. The field of environmental education has been making strides in this direction, incorporating key concepts of green chemistry and engineering for a more complete approach to sustainability. Green chemistry pulls from engineering, environmental health science, toxicology and environmental studies to provide a more systematic approach to solving problems, process and product design and overall innovation.

“Green chemistry is a new way to meet society’s needs without highly toxic chemicals and increasing pollution. It seeks healthy solutions for everyday chemicals and products, using less energy and natural resources. Green chemistry will also be an important tool as we address climate change and seek a sustainable future.”

—Barbara Warren  
Executive Director Citizens’  
Environmental Coalition

Preparing the next generation of educators at both the K-12 and university level to teach green chemistry is critical for providing the tools necessary to create a sustainable future. In Region 2, encouraging teacher colleges and related associations to include green chemistry and engineering in core science education programs could be one way of disseminating these tools more broadly. Additionally, providing chemists and professors with professional development through classes, workshops, webinars and other venues can help them in inculcating the next generation of scientists and engineers in the principles of green chemistry.

The following are some existing examples of how green chemistry concepts could be better incorporated into educational curricula associated with environmental, science and chemistry education:

- Putnam/Northwest Board of Cooperative Educational Services (P/NW BOCES) serves as a leader in the State with its Center for Environmental Education. By aligning and integrating environmental education concepts and character education into pre K-5 curriculum, programs, assemblies, field trips and professional development, P/NW BOCES has built a model for teaching and learning sustainability in K-12 schools.
- Requiring schools to teach environmental literacy is a movement that is gaining ground in many states, including those in Region 2. The New Jersey Commission on Environmental Education and its Inter-Agency Workgroup, for example, recently has issued a Draft Environmental Literacy Plan. Similarly, the New York State Outdoor Education Association has spearheaded the efforts of a multi-stakeholder group, including P/NW BOCES, the Science Teachers Association of New York State, Audubon, NYSDEC and others to develop a draft environmental literacy plan.
- Beyond Benign has teamed up with an advisory board of more than 10 chemistry departments across the country to develop the Green Chemistry Commitment. The Commitment is designed for educational institutions at all levels to provide a platform for changing chemistry education. Schools, colleges and universities will sign on to commit to changing curricula, laboratory exercises, course materials, and methods and research practices. Without changing chemistry education, our society will continue to produce scientists that lack the skills necessary to produce sustainable materials. The Green Chemistry Commitment is a leading effort to bring about change by fundamentally changing the education of future chemists.<sup>34</sup>
- Urban Advantage is a standards-based partnership program designed to improve students' understanding of scientific inquiry through collaboration between urban public school systems and science cultural institutions such as zoos, botanical gardens, museums and science centers. Working together, public schools, science-rich cultural institutions, and the New York City Department of Education have succeeded in improving the implementation of middle school scientific investigations. These partners remain committed to improving students' understanding of scientific inquiry and are excited

about its potential to increase scientific literacy for all eighth grade students in urban areas.<sup>35</sup>

- The New York Academy of Sciences Science Teachers Program connects teachers with the larger scientific community by creating linkages between students, teachers and working scientists. The program helps educators make science learning more relevant and exciting by providing them with access to resources that they can apply in classroom settings. Lesson plans, lectures, workshops and multimedia resources are available for teachers of all grade levels in chemistry, biology, earth science, green science, mathematics and physics. The Academy creates materials that are audience and demand-driven. “The academy is poised to respond to the demand of teachers and students looking for sustainability education,” according to Meghan Groome, Ph.D., who is the Academy’s Director of K-12 science education initiatives. As an educational leader in the region, the Academy would be open to collaboration with other state agencies and partnering organizations to help meet the demand for greater green chemistry and green engineering education.
- The Academy’s Afterschool STEM Mentoring Program matches afterschool program providers in New York City and Newark with graduate student members of the Academy’s Science Alliance, which provides support and career mentoring to 8,000 graduate students and postdoctoral fellows in STEM (science, technology, engineering and mathematics) disciplines. Graduate students are trained in STEM-related curricula and placed in afterschool programs as instructors and mentors, seeking to both solidify foundational science education and foster better science communications by young researchers. This program provides a model for integrating STEM subjects both at the academic and K-12 level simultaneously. Strong science skill-building programs such as this could be an excellent way to disseminate green chemistry knowledge and tools through an existing pathway.<sup>36</sup>
- The New York State Pollution Prevention Institute (NYSP2I) is developing a set of green chemistry curriculum modules for use in state high school chemistry classes. The goal of the green chemistry modules is to reduce the amount of hazardous materials in NYS high school labs while introducing high school students to sustainability concepts. NYSP2I is working with SUNY Brockport and SUNY Potsdam to develop the modules, which fully conform to the state Regents Standards, as a drop-in replacement for current high school chemistry labs. Once complete, the modules will be available to teachers for use in their classrooms via the NYSP2I website.<sup>37</sup>

Through these example statewide and regional initiatives, science education could be enhanced to include environmental topics, such as green chemistry and green engineering, helping to better prepare students to enter the workforce with the skills to solve global and local environmental problems.

## Community Environmental Health Collaboration

For decades, environmental health scientists have compiled evidence of toxic exposures and environmental threats, as well as public health and economic harms, from existing patterns of chemical usage associated with commerce. By uniting with scientists and public health research institutions, advocacy organizations have the potential to leverage funding and research to find solutions and alternatives to chemicals of concern.

The following are key examples of campaign successes for the health, environment, and justice of New Yorkers:

- In 2008, the Center for Health, Environment and Justice (CHEJ) worked with Citizens' Environmental Coalition (CEC), the Alliance for a Toxic-Free Future (ATFF) and seven state agencies to develop an innovative State Agency Green Purchasing Policy to avoid purchasing products with priority toxic chemicals. Governor David Paterson issued the Green Purchasing Executive Order in April 2008.<sup>38,39</sup>
- CHEJ, CEC and ATFF were instrumental in establishing NYSP2I in 2007. In 2008, NYSP2I received \$2 million from the state budget. The Institute will help businesses reduce their use of toxic chemicals by providing technical assistance, research and development, and education on pollution prevention and green chemistry practices.<sup>40</sup>
- Clean & Healthy New York is dedicated to promoting safer chemicals, a sustainable economy and a safer world. Through partnerships with organizations such as NYSDEC, American Sustainable Business Council and NYSP2I, Clean & Healthy New York events (including the *Healthy Economy & Environment* Conference on December 6 and 7, 2011) have brought stakeholders together to explore how academia can be a partner for new, healthier products and processes: the role of public policy in spurring innovation; the power of green purchasing; and more. Celebrating and highlighting successes promotes and encourages more changes in protection of health and the environment in academia, schools, businesses and the public sector.<sup>41,42</sup>
- Healthy Schools Network, Inc., serves as a leading national voice for children's environmental health and has collaborated with EPA, CDC, university centers and NGOs.<sup>43</sup> Healthy and high performance schools improve children's health, energy efficiency, and teacher and school staff job satisfaction, while enhancing student performance and providing a healthier environment for building occupants. Key efforts include the following:

"When companies find inherently safer ways to make things, and inherently less toxic materials to use, we all benefit. New York is home to some great efforts, and we want to see more of this."

—Kathy Curtis, Executive Director for Clean and Healthy New York

- In 2006, NYSERDA and NYSDEC released comprehensive Healthy and High Performance School Design Guidelines for New York State schools. Healthy Schools Network worked to bring NYSDEC and NYSERDA together to create these guidelines and then served as an advisor to the project during its development.
- Leaders of a campaign across New York City for green construction won approval for Local Law 86 in 2005. As a result, the City's School Construction Authority researched and produced a Green Schools Guide, now linked to the city's \$13.2 billion five-year school capital plan.

## Assistance and Incentives

A variety of federal, state, regional and local funding sources are already supporting sustainable development, pollution prevention, renewable energy, clean technology, innovation and green jobs. Implicit in the larger scope of sustainable development, green chemistry provides the tools from the design stage of products and processes to invent, manufacture and produce safe, economical and effective products.

Industry has traditionally been a leader in promoting and implementing green chemistry technologies and practices. Assistance and incentives targeted at a variety of organizations, including both large and small enterprises, will help to further promote green chemistry and engineering, especially when those strategies are integrated into existing state level economic development planning and assistance services infrastructure. The following existing programs, resources and incentives are examples of resources which can be harnessed to promote green chemistry and engineering research and applications in industry:

**EPA Region 2** generally sponsors two grant programs open to qualified applicants on an annual basis: the P2 and the Source Reduction Assistance (SRA) grant programs. Each year Requests for Proposals (RFP) and competitions are held for each grant program. The RFPs for 2012 made available approximately a total of \$530,000 in funding for priority projects that prevent pollution through the use of sustainable tools, including green chemistry and green engineering.<sup>44</sup> NYSDEC and Rowan University are two current awardees that are implementing projects with different stakeholder groups by these funding mechanisms.

**NYSP2I's** creation of opportunities for innovation, environmental stewardship and production efficiency has been a central focus for the organization. Their recent Green Initiative Program is divided into two components: the Green Technology Accelerator Center (GTAC) and the Sustainable Supply Chain and Technology Program (SCC).<sup>45</sup>

- The GTAC program is designed to provide technical assistance to companies developing and commercializing green technologies and products. By leveraging NYSP2I's senior engineers and university partners, GTAC will provide technical assistance for existing companies or companies already established in incubators by testing their green technologies to validate claims of environmental improvement or "green" products.

GTAC will focus on “green technology” development, including, but not limited to, the following areas: green chemistry, material reuse/recycling, energy and/or water efficiency, sustainable building materials, toxics replacement or substitution, and remanufacturing.

- The goal of the SCC Program is to help position New York manufacturers in taking advantage of opportunities in global sustainable manufacturing and green supply chains through identification and communication of relevant non-regulatory standards and sustainability certification requirements necessary to enter new and emerging “green” markets. NYSP2I will provide companies with an assessment of their current manufacturing processes and identify steps necessary to meet sustainability scorecards or certifications. NYSP2I will also facilitate awareness of suppliers participating in the program to potential purchasers of their products and services.

**The New Jersey Economic Development Authority (NJEDA)** creates public/private partnerships to bridge financing gaps and to increase the business community’s access to capital with an emphasis on small and mid-size businesses and not-for-profit organizations. Through a variety of programs, NJEDA is a key stakeholder that supports and cultivates the green economy and innovation. Research and development companies focusing on utilizing green chemistry tools can benefit from several incentives, including the following:<sup>46</sup>

- **Business Employment Incentive Program (BEIP):** Companies seeking to relocate to, or expand, in New Jersey may be eligible for BEIP grants based on the number of new jobs created. By adding at least 25 qualified jobs (10 for qualifying technology companies) within two years, eligible companies can be reimbursed for up to 80 percent of gross withholding tax paid by new employees for up to 10 years, to a maximum of \$50,000 per employee over the course of the grant period.
- **Edison Innovation Angel Growth Fund (EIAGF):** Technology companies with minimum trailing 12 month commercial revenues of \$500,000 may be eligible for up to \$250,000 in subordinated convertible debt financing. Growth capital through the EIAGF can be used for key hires, product rollout, product enhancement and marketing/sales.

**New Jersey Clean Energy Resource Network (NJ CERN)** maintains an easily searchable database of over 300 federal and New Jersey state financial incentives, regulations, permitting and green job training programs. The New Jersey Meadowlands Commission Business Accelerator developed NJ CERN in collaboration with the Rutgers University EcoComplex, the University’s environmental research and extension center.<sup>47</sup>

**The New York State Office of General Services** has a strong set of green procurement policies as a result of Executive Orders and State Education Laws. These policies can encourage green chemistry research and the use of less hazardous chemicals by companies seeking consideration to do business with state agencies. Noteworthy policies include:

- Directing state agencies to reduce the environmental impact of cleaning of state facilities.
- Directing all public and private elementary and secondary schools in New York State to use environmentally sensitive cleaning and maintenance products.
- Establishing a state green procurement and agency sustainability program.

**New York Empire State Development (NYESD)** has embraced Regional Councils to advance economic development, representing a fundamental shift in planning and offering an opportunity for green chemistry and engineering to play a major role in job creation and innovation. Leveraging the focus and target of the Regional Council funding to include more programs centered on green chemistry research and education is one way for regions to gain a distinct advantage in driving economic growth and job creation.<sup>48</sup>

“Regional collaborations and planning is a roadmap to get New Yorkers back to work. The plans submitted by all 10 regions were truly extraordinary. For the first time, we are putting the power of the State Government behind the innovation of our people, giving them the tools to rebuild our economy.”

—Andrew Cuomo  
New York Governor  
December 18, 2011

The following are available funds at NYESD for pollution prevention:

- The Innovate New York Fund is a \$26 million seed stage equity fund that targets innovation, job creation and high growth entrepreneurship throughout the state.
- The Environmental Improvement Fund provides up to \$1 million to help businesses capture the economic benefits associated with pollution prevention, waste reduction, reuse, recycling, and sustainable products and process technologies.

**NYSERDA** has a variety of programs—including environmental product development—that green chemistry and engineering principles could strengthen, helping broaden the scope of its sustainability efforts. *Green Jobs Green New York* is a statewide program at NYSERDA to promote energy efficiency and the installation of clean technologies to reduce energy costs and reduce greenhouse gas emissions. The program will support sustainable community development and create opportunities for green jobs.

Examples of NYSERDA-funded collaborative partnerships include:

- *e2e Materials, Inc.*: The e2e Materials green composite, a replacement to particleboard or medium density fiberboard (PB/MDF), is made from natural fibers with soy-based resins to replace petroleum-based polymers and wood/synthetic fiber sources. An inherently safer process without the use of harmful formaldehyde, e2e Materials are also thinner, stronger and lighter than particleboard or medium density fiberboard (PB/MDF). At similar production volumes, the cost-effectiveness compares favorably to a PB/MDF plant. Major reductions in energy consumption are possible because the e2e Materials boards are thinner and the operating temperature is lower.<sup>49</sup>

- *Ecovative Design LLC*: Eben Bayer and Gavin McIntyre invented a new method for binding together insulating particles to create Greensulate™, a substitute insulating foam. The two inventors were inspired by mushrooms growing on wood chips, and by observing how the fungal mycelia strongly bonded the wood chips together. Rather than just decreasing the environmental impact of conventional polystyrene foams, this invention creates a new paradigm where composite materials literally are grown, harnessing the efficiency of nature. Shortly after founding the company Ecovative Design LLC, Bayer and McIntyre won small grants from the American Society of Mechanical Engineers and the National Collegiate Inventors and Innovators Alliance. This funding was used to create initial samples of the material, enabling the company to win bigger grants from NYSERDA and EPA to further develop the products. Since then, Ecovative has won many more awards and grants that have enabled the company to continue to grow and accelerate production of these revolutionary eco-friendly materials. The company has also submitted to a third party certified lifecycle analysis of its operations, which will be available to the public shortly.<sup>50,51</sup>

“Governor Cuomo has established New York State as a leader in energy efficiency initiatives while at the same time expanding the State’s diverse renewable energy portfolio. These investments continue to highlight New York’s commitment to growing its clean-energy economy, protecting the environment and reducing energy costs for all New Yorkers.”

—Francis J. Murray Jr.,  
President and CEO,  
NYSERDA

## Professional Societies

Professional societies can also be initiators of education, recognition, business incentives and policy recommendations. Below is a short list of a few of the key societies that are well established and trusted leaders, and are in a position to promote green chemistry.

- The American Chemical Society (ACS) is an independent membership organization which represents professionals at all degree levels and in all fields of chemistry and sciences that involve chemistry. The society hosts national and regional conferences, prints professional publications and promotes the best interests of the field. The ACS Committee on Professional Training (CPT) promotes excellence in postsecondary chemistry education and provides leadership to the ACS in the professional training of chemists. The CPT goals are: to conduct and enhance an approval procedure for bachelor’s degree programs in chemistry; to promote effective practices and innovations in chemistry education; and to promote broad participation in chemistry to enrich the profession with the talents of a diverse group of individuals.<sup>52</sup> If the CPT were to call for training in green chemistry, it would have a catalyzing affect on the education of future chemists.

- The American Association of Engineering Societies (AAES) represents the interests of engineers across America. The organization serves as a voice to policymakers when addressing issues with engineering implications. AAES holds numerous conferences as well as providing awards to students and businesses promoting the best practices within the various fields of engineering.<sup>53</sup> Chemistry professionals and students may benefit from approaching problems using lifecycle analysis and systems thinking, which is actively practiced in chemical and mechanical engineering. Greater collaboration between the fields at the design stage can save time, energy and resources.
- The National Collegiate Inventors and Innovators Alliance (NCIIA) supports technology innovation and entrepreneurship in universities and colleges to create experiential learning opportunities for students and successful, socially beneficial businesses. The NCIIA provides faculty with funding for courses and programs, opportunities for recognition, and entrepreneurship education training and networking. The organization also provides student start-ups with early stage funding, business strategy development training, mentoring and investment.<sup>54</sup> Green chemistry innovation directly aligns with the types of projects NCIIA is seeking to support and fund. This group is another example of how to promote and support green chemistry innovation at the academic level.

## Region 2 Leadership and Collaborative Networks

Region 2 can draw inspiration from some models of collaborative networks available from other parts of the country. For additional information, see the Appendix. In addition, there are several organizations that already demonstrate elements of leadership and regional collaboration capability within their organizations and through their partnerships. NYSDEC, NJDEP and the New York Academy of Sciences are all key contributors, with examples of previous sustainability and P2 work that can be shaped to expand the conversation to explicitly include green chemistry and engineering initiatives, research, practice and projects. Green chemistry can enhance current networks dedicated to sustainable development and eco-innovation.<sup>55</sup>

### New York State Department of Environmental Conservation

NYSDEC plays a vital role in coordinating and collaborating with a variety of stakeholder groups in New York State in support of its green chemistry initiatives. The Toxics Reduction & Green Chemistry Section, within the Division of Materials Management, has undertaken the task of advancing green chemistry in New York State high schools. Through strategic partnerships with the NYSED, New York County's Board of Cooperative Educational Services (NYC BOCES), Siena College and other stakeholders, NYSDEC has with available financial resources introduced green chemistry principles and practices that can be woven into the environmental education framework and provide chemistry teachers with tools that were previously not available to reduce toxics in their chemistry laboratories.

In addition, the leadership displayed by NYSDEC will continue to potentially connect the green chemistry education expertise of Beyond Benign with Siena College chemistry professors,

College of Saint Rose staff and professors, along with select high school science teachers and administrators. Cultivation of these relationships will foster a regionally-based and sustainable model for integrating green chemistry curriculum into the educational system.

In a complementary manner, NYSDEC's intern program, also funded through a grant from EPA Region 2, is providing invaluable opportunities for college students in science and engineering disciplines to assist local industries and businesses in implementing green chemistry and pollution prevention strategies while gaining valuable workplace skills and experience in their chosen field. NYSDEC works directly with industry to develop a work plan for summer interns to solve environmental problems that have been identified by a particular company.

### **New Jersey Department of Environmental Protection**

A major role of NJDEP's Office of Economic Growth and Green Energy is to create opportunities for local New Jersey businesses to thrive while creating solutions for energy challenges. Linking with the New Jersey Business Incubation Network (NJBIN) to provide a set of green chemistry seminars is a powerful way for the region to use its resources effectively.<sup>56</sup> NJBIN is a collaborative statewide community of business experts and resource facilities dedicated to enhancing the commercial success of early stage and expansion stage entrepreneurial companies, growing higher paying jobs and supporting the economic growth strategy for the state. Start-up companies still in the R&D stage are candidates for tools such as green chemistry and green engineering that can enhance competitive advantage. Implementing green chemistry principles from the initial design stage eliminates the costs associated with retrofitting a manufacturing plant and will provide safer chemical products and processes, more effective performance standards and cost saving advantages.

In 2010, more than 500 client companies supported the New Jersey Business Incubation Network and:

- Created/retained over 1,800 higher paying jobs
- Generated \$155 million in revenues
- Brought \$91 million in 3rd-party funding to New Jersey
- Graduated 54 self-sustaining companies

### **New York Academy of Sciences**

The Academy has a history in advancing discussion in diverse areas of science and mobilizing scientific discoveries from the laboratory and the field for nearly 200 years. Capitalizing and building off the strength of this well-established network is a potentially vital opportunity to move green chemistry into the chemistry mainstream.

As an example of their past experience, the 2007 Academy report, *Environmental Research and Monitoring Needs in New York State*, provides direction for environmental research with a focus on pollution for NYSERDA, other state, regional, and national research funding organizations and agencies, the scientific community, public benefit organizations, and policymakers.<sup>57</sup> The

report lends credence to the view that green chemistry and engineering have key roles in meeting the sustainability goals of the region.

As leaders in the process to set clean energy goals for the state, the Academy also recently published a white paper, *Innovation and Clean Technology in New York State: A New Economic Engine*<sup>58</sup>, which was used in the Climate Action Plan process for New York State. As advocates for clean technology, the Academy also recognizes that green chemistry and engineering principles can play a role in mitigating the toxicity impacts of future technologies such as photovoltaic and advanced batteries, as well as in the early design phases of nanotechnologies.

## CONCLUSION

The ideas presented at the 2011 workshop, *Unleashing Green Chemistry and Engineering in Service of a Sustainable Future*, offer promise and opportunity to many organizations in Region 2. This report summarizes a sample of the existing programs and partners within the region, as well as identifies opportunities for collaboration between stakeholders in green chemistry and green engineering. Making use of existing programs, organizations, and collaborative capacities will help create a healthy environment while fostering prosperity and sustainable economic growth. The collective efforts of stakeholders within the region will ensure the use of existing local resources; strengthen the local educational system in order to produce the human capital needed to fill jobs in green chemistry; and enhance public policy to support industrial innovation in green chemistry and sustainable technologies. Many stakeholders at the workshop expressed interest in promoting awareness, knowledge and education of green chemistry to their various constituents; we encourage further efforts to support the dissemination of this emerging and vital discipline.

Region 2 has many organizations in place to spread green chemistry awareness and knowledge through the avenues of individuals, businesses, schools, government and communities. It is well-poised to be a national and international leader in green chemistry innovation by unleashing solutions to not only the region's environmental challenges but also the world's. Building off strong regional collaborations is a key starting place for mobilizing a large set of stakeholders.

This report is an invitation to Region 2 stakeholders to both extend their own work and to further collaborate in order to cultivate various emergent pathways of opportunity through our collective power and unique regional capabilities. Through our creativity we can expand the conversation to ensure that 21<sup>st</sup> century education and commerce are rooted in the principles of green chemistry and engineering.

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- <sup>14</sup> Merck home page: <http://www.merck.com/index.html>
- <sup>15</sup> Atom economy: an assessment of a chemical process that compares the number of atoms of all starting materials and reagents to the number of atoms incorporated into the final product(s). An ideal chemical process has an atom economy of 100%, in which all atoms in the starting materials and reagents are in the final product, with no atoms wasted.
- <sup>16</sup> E-factor: short for environmental impact factor. It measures the efficiency of a chemical process, with a focus on generated waste. The e-factor is defined as the ratio of kilograms of waste produced to kilograms of the desired product produced.
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- <sup>29</sup> New Jersey Department of Protection Governor's Environmental Excellence Awards page: <http://www.state.nj.us/dep/eeawards/>
- <sup>30</sup> U.S. Environmental Protection Agency Environmental Quality Awards home page: <http://www.epa.gov/region2/eqa/>
- <sup>31</sup> Chemagination home page: <http://www.princeton.edu/~pacs/chemagination.htm>
- <sup>32</sup> Lauter, L. "Chemagination: The Role of Chemistry in Everyday Life and the Future," Poster presentation at ACS Princeton Chapter.
- <sup>33</sup> U.S. Department of Education. "Obama Administration Names 78 Schools in 29 States and D.C. as First-Ever U.S. Department of Education Green Ribbon Schools," April 23, 2012. URL: <http://www.ed.gov/news/press-releases/obama-administration-names-78-schools-29-states-and-dc-first-ever-us-department->
- <sup>34</sup> Green Chemistry Commitment home page: [www.greenchemistrycommitment.org](http://www.greenchemistrycommitment.org)
- <sup>35</sup> Urban Advantage home page: <http://www.urbanadvantagenyc.org/home>
- <sup>36</sup> New York Academy of Sciences Education page: <http://education.nyas.org/>
- <sup>37</sup> New York State Pollution Prevention Institute home page: <http://www.rit.edu/affiliate/nyssp2i/>
- <sup>38</sup> New Jersey Business Incubation Network home page: <http://www.njbin.org>
- <sup>39</sup> New York State Office of General Services Green Purchasing page: <http://www.ogs.state.ny.us/purchase/GreenPurchasing.asp>
- <sup>40</sup> NYSP2I home page: <http://www.rit.edu/affiliate/nyssp2i/>
- <sup>41</sup> Clean and Healthy New York home page: <http://www.cleanhealthyny.org/>

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- <sup>42</sup> Clean and Healthy New York. “Building NY’s Healthy Economy & Environment,” December 19, 2011. URL: <http://www.cleanhealthyny.org/2011/12/building-nys-healthy-economy-environment-.html>
- <sup>43</sup> Healthy Schools New York Programs page: [http://www.healthyschools.org/ny\\_program.html](http://www.healthyschools.org/ny_program.html)
- <sup>44</sup> U.S. Environmental Protection Agency Region 2 page: <http://www.epa.gov/region2/p2/>
- <sup>45</sup> NYSP2I Green Initiative Program: <http://www.rit.edu/affiliate/nysp2i/green-initiative-program>
- <sup>46</sup> New Jersey Economic Development Authority home page: <http://www.njeda.com/web/default.aspx>
- <sup>47</sup> New Jersey Clean Energy Resource Network home page: <http://njcern.rutgers.edu/Presentation/>
- <sup>48</sup> New York State Governor’s Press Office. “Governor Cuomo Announces \$785 Million in Economic Development Funding Through Regional Councils,” December 18, 2011. URL: <http://www.governor.ny.gov/press/12082011RegionalCouncils>
- <sup>49</sup> e2e Materials, LLC home page: <http://e2ematerials.com>
- <sup>50</sup> Ecovative Design profile on Crunchbase: <http://www.crunchbase.com/company/ecovative-designs>
- <sup>51</sup> New York State Governor’s Press Office. “Governor Cuomo Announces Clean Energy and Environmental Initiatives During Earth Week Cabinet Meeting,” April 26, 2012. URL: <http://www.governor.ny.gov/press/04262012earthweek>
- <sup>52</sup> American Chemical Society home page: <http://www.acs.org>
- <sup>53</sup> American Association of Engineering Societies home page: <http://www.aaes.org/>
- <sup>54</sup> National Collegiate Inventors and Innovators Alliance home page: <http://nciia.org/>
- <sup>55</sup> Organization for Economic Co-operation and Development. *Sustainable Manufacturing and Eco-Innovation: Framework, Practices and Measurement—Synthesis Report*, 2009. URL: <http://www.oecd.org/dataoecd/15/58/43423689.pdf>
- <sup>56</sup> New Jersey Business Incubation Network home page: <http://www.njbin.org/>
- <sup>57</sup> New York Academy of Sciences. *Environmental Research and Monitoring Needs in New York State: A Multi-Year Research Plan for the New York State Energy Research and Development Authority’s Environmental Monitoring, Evaluation, and Protection Program*, 2007. URL: <http://www.nyserda.ny.gov/en/Page-Sections/Environmental-Research/EMEP/~media/Files/EE/EMEP/Climate%20Change/emepplan2007.ashx>
- <sup>58</sup> New York Academy of Sciences. *Innovation and Clean Technology in New York State: A New Economic Engine*, 2010.

## APPENDIX: SUPPLEMENTARY WEB LINKS

### Videos

EPA Green Chemistry Video: <http://www.youtube.com/watch?v=rIE4T2HLW7c>

K-12 School Webinar on Energy Efficiency and PCBs in New Jersey:

[http://www.cleanairinfo.com/energyefficiencytraining/nj\\_info.html](http://www.cleanairinfo.com/energyefficiencytraining/nj_info.html)

### General Information: EPA Programs

Home Page: <http://www.epa.gov/>

Green Chemistry Program: <http://www.epa.gov/greenchemistry/>

Green Chemistry Challenge: <http://www.epa.gov/greenchemistry/pubs/pgcc/presgcc.html>

Design for Environment Program: <http://www.epa.gov/dfe/index.htm>

ORD Green Chemistry Factsheet: <http://www.epa.gov/ord/priorities/chemicalsafety.htm>

Green Engineering Program: <http://www.epa.gov/oppt/greenengineering/>

Chemicals Management: <http://www.epa.gov/oppt/existingchemicals/index.html>

E3 (Economy, Energy and the Environment): <http://www.e3.gov/>

Region 2 P2 and SRA Grants Programs: <http://www.epa.gov/region02/p2/grants.htm>

### General Information: Non-EPA Related Programs

#### Universities

Institute for Green Science at Carnegie Mellon: <http://www.chem.cmu.edu/groups/collins/>

Gordon College Green Chemistry Program: <http://www.gordon.edu/greenchemistry>

Lowell Center for Sustainable Production at the University of Massachusetts:

<http://www.sustainableproduction.org/>

Toxics Use Reduction Institute at the University of Massachusetts: <http://www.turi.org/>

Green Chemistry at the University of Oregon: <http://greenchem.uoregon.edu/>

The College of Engineering – Chemical Engineering, Rowan University:

<http://www.rowan.edu/colleges/engineering/programs/chemical/rowanche/news.html>

Green Chemistry at the University of Scranton:

<http://academic.uofs.edu/faculty/cannm1/greenchemistry.html>

Center for Green Chemistry & Green Engineering at Yale University:

<http://greenchemistry.yale.edu/>

New York State Pollution Prevention Institute at the Rochester Institute of Technology:

<http://www.rit.edu/affiliate/nysp2i/>

## **NGOs**

ACS Green Chemistry Institute:

[http://portal.acs.org/portal/acs/corg/content?\\_nfpb=true&\\_pageLabel=PP\\_TRANSITIONMAIN&node\\_id=830&use\\_sec=false&sec\\_url\\_var=region1](http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_TRANSITIONMAIN&node_id=830&use_sec=false&sec_url_var=region1)

AIChE (American Institute of Chemical Engineers): <http://www.aiche.org/>

Beyond Benign: <http://www.beyondbenign.org/>

Beyond Benign, Green Chemistry Commitment:

<http://greenchemistrycommitment.org/index.html>

Beyond Benign, Green Chemistry Resources:

<http://www.beyondbenign.org/greenchemistry/resources.html>

Beyond Benign Additional Green Chemistry Resources:

<http://www.greenchemistrycommitment.org/resources.html>

Clean Production Action: <http://www.cleanproduction.org/Home.php>

Institute for Local Self-Reliance: <http://www.sustainableplastics.org/resources>

Responsible Purchasing Network: <http://www.responsiblepurchasing.org/>

Safer Chemicals, Healthy Families Coalition: <http://saferchemicals.org/>

Warner Babcock Institute: <http://www.warnerbabcock.com/>

## **New York State Resources**

NYSDEC Green Chemistry Project: <http://www.dec.ny.gov/education/77750.html>

NYSERDA & Biomimicry: <http://www.nyserda.ny.gov/en/Programs/Research-and-Development/Biomimicry.aspx>

NYESD Division of Science, Technology and Innovation (NYSTAR): <http://esd.ny.gov/nystar/>

New York State Department of Labor, Safety and Health:

[http://www.labor.state.ny.us/workerprotection/safetyhealth/dosh\\_pesh.shtm](http://www.labor.state.ny.us/workerprotection/safetyhealth/dosh_pesh.shtm)

The JustGreen Partnership: <http://just-green.org/>

Clean and Healthy New York: <http://www.cleanhealthyny.org/>

## **Companies**

American Sustainable Business Council: <http://www.asbcouncil.org/>

BioAmber, Inc.: <http://www.bio-amber.com/>

Bristol-Myers Squibb: [http://www.bms.com/sustainability/go\\_green/Pages/default.aspx](http://www.bms.com/sustainability/go_green/Pages/default.aspx)

Construction Specialties: <http://www.c-sgroup.com/>

e2e Materials, Inc.: <http://e2ematerials.com/>

EcologicSolutions: <http://ecologicsolutions.com/>

Ecovative Design LLC: <http://www.ecovatedesign.com/>

Green Chemistry and Commerce Council: <http://www.greenchemistryandcommerce.org/>

Merck & Co., Inc.: <http://www.merckresponsibility.com/priorities-and-performance/environmental-sustainability/home.html>

NatureWorks LLC: <http://www.natureworksllc.com/>

NovaSterilis, Inc.: <http://www.novasterilis.com/>

SiGNa Chemistry: <http://signachem.com/>

## **Education**

Children's Health Protection:

[http://yosemite.epa.gov/ochp/ochpweb.nsf/content/Whatwe\\_educat.htm](http://yosemite.epa.gov/ochp/ochpweb.nsf/content/Whatwe_educat.htm)

The Cloud Institute for Sustainability Education: <http://www.cloudinstitute.org/>

Green Education Foundation: <http://www.greeneducationfoundation.org/>

Safe Science by the Connecticut Science Teachers Association: [http://www.csta-us.org/Safe\\_Science.htm](http://www.csta-us.org/Safe_Science.htm)

Safety in the Science Classroom by the National Science Teachers Association: <http://www.nsta.org/portals/safety.aspx?print=true>

Next Generation Science Standards: <http://www.nextgenscience.org/>

Schools Chemical Cleanout Campaign (SC3):

<http://www.epa.gov/osw/partnerships/sc3/index.htm>

## Procurement

The New York State Office of General Services (NYSOGS):

<http://www.ogs.ny.gov/purchase/EnvironmentPurchasing.asp>

Sustainable Biomaterials Collaborative (“The BioSpecs for Purchasers”):

<http://www.sustainablebiomaterials.org/criteria.purchasing.php>

## Collaborative Networks

Great Lakes Green Chemistry Network: <http://www.glgc.org/>

Michigan Department of Environmental Quality Green Chemistry:

[http://www.michigan.gov/deq/0,4561,7-135-3585\\_49005---,00.html](http://www.michigan.gov/deq/0,4561,7-135-3585_49005---,00.html)

Michigan Green Chemistry Clearinghouse: <http://www.migreenchemistry.org/>

NEWMOA Interstate Chemical Clearinghouse (IC2): <http://www.newmoa.org/prevention/ic2/>

New England Green Chemistry Consortium: <http://negcc.org/>

## Biomimicry

Biomimicry 3.8: <http://biomimicry.net/>

Terrapin Bright Green:

<http://www.terrabinbrightgreen.com/ideas/ideaaindepth.php?ideaaid=z1mpGoCXru9RXOPM5iW6>

## Industrial Ecology

International Society for Industrial Ecology: <http://www.is4ie.org/>

The New York Academy of Sciences – Industrial Ecology, Pollution Prevention and the New York/New Jersey Harbor: <http://www.nyas.org/WhatWeDo/Harbor.aspx>

Yale School of Forestry and Environmental Studies, Center for Industrial Ecology:

<http://cie.research.yale.edu/>

## Innovation

Andersen, M. “An Innovation System approach to Eco-innovation – Aligning policy rationales,” Proceedings from The Greening of Policies—Interlinkages and Policy Integration Conference, Berlin, 2004. URL: [http://www.cgiar-ilac.org/files/andersen\\_innovation.pdf](http://www.cgiar-ilac.org/files/andersen_innovation.pdf)

Block, F. and Keller, M. “Where Do Innovations Come From? Transformations in the U.S. National Innovation System, 1970–2006,” Information Technology & Innovation Foundation, July, 2008. URL: [http://www.itif.org/files/Where\\_do\\_innovations\\_come\\_from.pdf](http://www.itif.org/files/Where_do_innovations_come_from.pdf)

Mahdjoubi, D. "Mapping the Regional Innovation Systems," University of Texas School of Information, 1998. URL: <http://www.ischool.utexas.edu/~darius/13-Map-Reg-Ino-Sys.pdf>



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